

FINITE-DIFFERENCE MODELING OF 3-D ANISOTROPIC WAVE PROPAGATION USING VARIABLE GRID SPACING

Aoife Toomey and G. M. Hoversten

Contact: Aoife Toomey, 510/486-6091, actoomey@lbl.gov

RESEARCH OBJECTIVES

Finite-difference modeling is routinely carried out to aid interpretation of seismic data acquired during hydrocarbon exploration. Most hydrocarbon reservoirs are overlain by low-velocity sediments, whose effects on the wavefield must be considered in order to successfully image deeper structures. However, the computational expense associated with finite-difference modeling is greater for low-velocity materials than for high-velocity materials. Including the effects of anisotropy on the seismic wavefield further increases the computational expense. Three-dimensional anisotropic finite-difference modeling has thus been restricted to small-scale models, unrealistic velocity structures, or long wavelengths due to its demand on computer time and memory. This research overcomes these limitations by using parallel computation and improved computational algorithms, enabling larger and more realistic geological models to be tackled.

APPROACH

We are using a fourth-order staggered-grid finite-difference (FD) solution to the wave equation. In a fourth-order scheme, the wavefield must be sampled with at least five grid-points per seismic wavelength to avoid numerical dispersion. Geological models containing low-velocity zones require fine discretization, and hence a large number of gridpoints, because of the shorter seismic wavelengths in these zones. When a uniform grid is used, oversampling of the wavefield occurs in high-velocity zones. Using variable grid spacing improves the efficiency of the FD method by partially avoiding this oversampling. We are using the variable-gridding scheme developed by Pitarka (1999). The grid spacing is adapted to the velocity structure using spatial differential operators designed for grids with nonuniform spacing. The coefficients to the spatial differential operators depend on the spacing between grid-points and are calculated at the beginning of the simulation.

ACCOMPLISHMENTS

We have implemented the 3-D variable-gridding anisotropic FD code to run on a 30-processor Beowulf cluster using message passing interface (MPI). Pentium III processors with 2 GB RAM and speeds ranging between 1 GHz and 1.4 GHz were used. On a single processor machine, model sizes were limited to $200 \times 200 \times 200$ gridpoints. This has increased to $620 \times 620 \times 620$ on the cluster (a 30-fold increase).

The accuracy of the variable-gridding code was tested for a homogeneous anisotropic model with the elastic properties of shale (a transversely isotropic material). We used a mesh with a constant grid spacing of 6 m in the two horizontal

directions. The vertical grid spacing decreased abruptly from 6 m to 3 m within a 300 m thick layer. A 20 Hz Ricker wavelet was used as a pressure source. Figure 1 shows a snapshot of the wavefield showing quasi-P- and -S-waves and a pure SH wave. Horizontal black lines mark the change in grid spacing, which clearly has no effect on the wavefield.

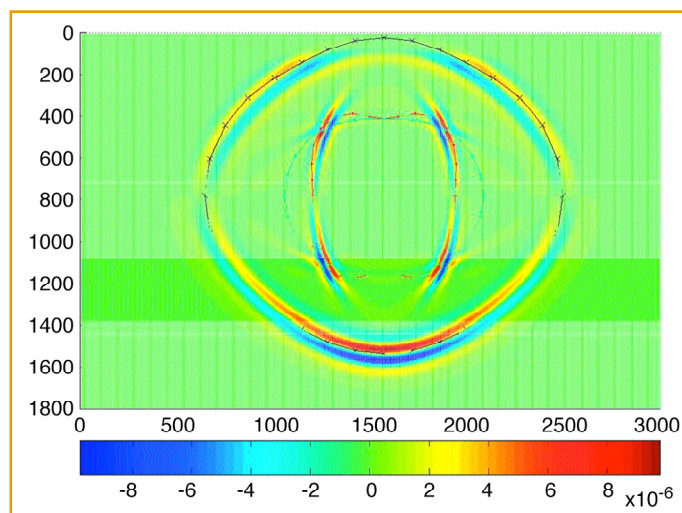


Figure 1. Snapshot of the wavefield in a homogeneous VTI model with vertical variations in grid-spacing indicated by thick black lines. Quasi-P and -S waves and a pure SH wave are unaffected by the change in grid-spacing.

SIGNIFICANCE OF FINDINGS

Our results show that variable-gridding and parallel computation can be used to reduce the computational expense associated with finite-difference modeling without any sacrifice in accuracy. These tools will enable us to incorporate more realistic velocity structure and geological complexity in large-scale 3-D anisotropic finite-difference modeling.

RELATED PUBLICATION

Pitarka, A., 3-D elastic finite-difference modeling of seismic motion using staggered grids with nonuniform spacing. *Bull. Seism. Soc. Am.*, 89(1), 54-68, 1999.

ACKNOWLEDGMENTS

This work was supported by the Assistant Secretary for Fossil Energy, Office of Natural Gas and Petroleum Technology, through the National Petroleum Technology Office, Natural Gas and Oil Technology, of the U.S. Department of Energy under Contract No. DE-AC3-76SF00098.

